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IN EXTERIOR BALLISTIC MEASUREMENTS

by

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ABSTRACT The importance of making use of GPS measurement systems to carry out external measurement track determinations is briefly described. Test measurement levels which have been reached inside and outside China are elucidated as well as problems which exist. Pulse modulation and demodulation technologies to effectively resolve test measurement accuracies are put forward. Opting for the use of time interval measurements in place of phase measurements, it is possible to effectively make systems with the same frequencies and different frequencies attain ns level group time delay measurement precisions, and it is possible to help in resolving GPS system zero correction difficulties.

KEY WORDS +Group time delay Frequency conversion Global positioning system +Frequency shift system

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1 INTRODUCTION

In the realm of astronavigation--speaking in terms of rockets and missiles--precise determination of their flight tracks is very important. The global positioning system (GPS) is a radio positioning, navigation, and time transmission system which is all weather continuous and global, developed by the U.S. Defense Department. Making use of high precision GPS positioning technologies, it is possible to carry out rocket or missile track determination measurements. The GPS measurement system is a set of transmiting and receiving measurement systems. Transmiters on board missiles use the S wave band to transmit L1 signals sent out by GPS NAVSTAR in the visible range. Ground measurement receiving equipment receives transmited signals from multiple GPS NAVSTAR's. Pseudo ranges and pseudo range rates of change are measured in order to precisely determine the space positions of flight targets equiped with transmiters. See Fig.1. Due to the fact that GPS measurement systems no longer deploy high precision atomic clocks, ground time is GPS system time calculated relying on extra information. As a result, ground equipment zero value calibration acting as common data presents very high requirements.

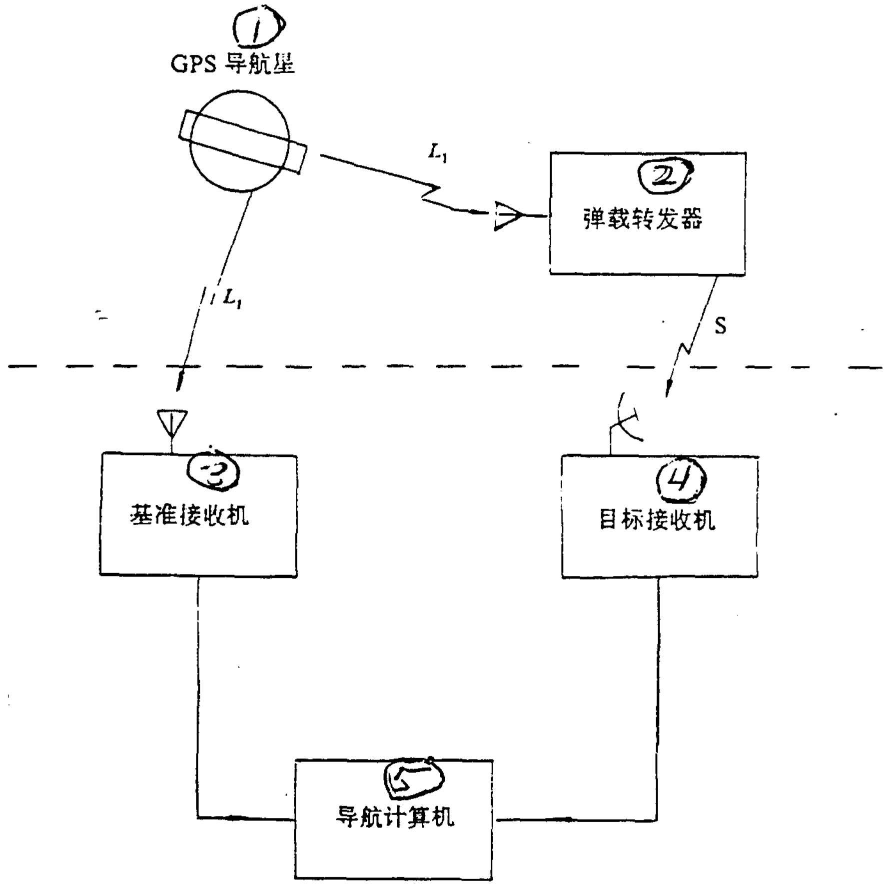


Fig.1 GPS Range Finding System Schematic

Key: (1) NAVSTAR (2) Transmiter on Board Missile
(3) Reference Receiver (4) Target Receiver (5) Navigation Computer

The basic principle of range finding systems is to measure propogation delays (transmission times) associated with radio signals at the measured distance in order to calculate ranges, that is, ρ is:

$$\rho = c\tau \tag{1}$$

In the equation, τ is the difference between the instant a signal is transmited from a certain satellite and the instant receivers receive it. c (illegible) is the speed of propogation of electromagnetic waves in a vaccuum. However, actual τ's also include delays associated with transmiting and receiving systems. The speed of transmission of radio signals within receiving and

transmiting systems is also not the speed of light. Moreover, the calculations of actual distances also do not include these partial delays. In this way, errors will be brought into range /62 determinations, thereby influencing the precision of range finding.

As a result, the measurement of delay amounts associated with receiving systems and transmiting systems themselves then become an important link in external missile measurements. The precision of measurements of these delay amounts directly influence rangefinding precision. From equation (1), it is possible to know that, if the τ measurement error is 1ns, and c is selected as the speed of light 3x108 m/s, then, the error associated with ρ is 0.3m . There is some engineering which already requires attaining 1m rangefinding accuracies. However, looking at the technological levels inside and outside China at the present time, actual test measurement methods which are able to be used in engineering and, in conjunction with that, attain ns level measurement precisions have still not been found. As a result, test measurements which resolve high precision group time delays become a pressing matter. Making use of advanced laboratory equipment and rich practical operating experience--on the foundation of large amounts of experimentation and analysis--we do research on a set of group time delay test measurement systems. The systems in question are not only capable of reaching ns levels in precision. Moreover, preliminary gropings are made at resolving difficulties associated with variable frequency system group time delay test measurements, in order to increase missile external measurement precisions to provide a technological base. Discussions are then carried out at the present time on a number of problems in principles and practical applications during group time delay measurements.

2 BASIC CONCEPTS AND PRINCIPLES

2.1 Group Time Delays

Group time delays are one type of transmission characteristic parameter inherent in linear systems and networks. They include two areas. One is the magnitude of group time delays themselves determining the magnitudes of system and network signal propogation time delays, that is, absolute group time delays. The second is the existence of intimate relationships between group time delay characteristics and signal propogation distortion, that is, relative group time delays. Here, the meaning of "group" has two levels. On the one hand, transmission signals must be group signals, that is, complex signals or wave groups composed of a good number of frequency components associated with frequencies which are very close to each other in accordance with a certain method or pattern. In conjunction with this, various types of already modulated signals (AM, FM, PM) using telemetry encryption to carry out modulation on high frequency carrier waves for their production are group signals. On the other hand, group refers to system time delays having to be time delays associated with entire wave groups.

The mathematical expression associated with group time delays is

$$\tau = -\,d\varphi(\omega)\,/\,d\omega \tag{2}$$

The geometrical meaning of group time delays is as shown in Fig.2.

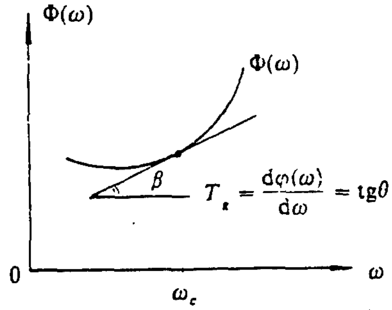


Fig.2 Geometrical Meaning of Group Time Delay

The group time delay shown in Fig.2 refers to time delays produced by systems and networks on signals as a whole when group signals go through linear systems or networks. It is also designated signal energy propogation time delay or absolute time delay. It represents the time period required by wave group signal energies from system input terminals to system output terminals. It is a measure of the size of energy propogation.

2.2 Envelope Time Delays

When signals go through systems, envelopes associated with system output signals have a time delay with regard to input signal envelopes. This time delay is designated as system envelope delay.

Due to the fact that signal envelopes are tracks associated with maximum amplitude values for signals synthesized from various wave group components as a function of time, envelope time delays, therefore, are capable--under certain conditions--of representing propogation time delays for wave group signal energies. In addition, because envelope wave forms for signals that have already been modulated and wave forms of modulation signals are the same, as a result, envelopes also represent group signal information components. Therefore, envelope time delays have very important significance with regard to signal energy transmissions. Moreover, under certain conditions, they are capable of taking the place of group time delays. This is also very important with respect to group time delay test measurements.

Below, amplitude modulation signals are taken as an example, deriving mathematical expressions associated with envelope time delays.

Assuming that a1(t) is a simple amplitude modulated signal, its analytic form is: /63

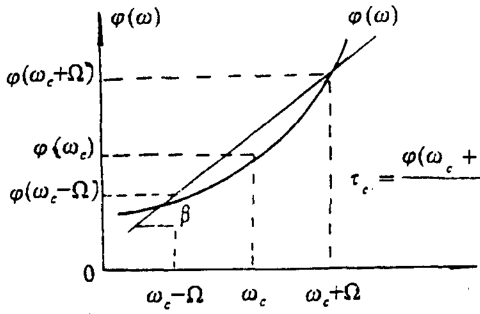
$$a_1(t) = A_0(1 + m\cos\Omega t)\cos\omega_c t \tag{3}$$

In the equation, Ao is amplitude. m is modulation index. Ω is modulation frequency. ωc is carrier wave frequency.

Expanding equation (3), one obtains:

$$a_1(t) = A_0\cos\omega_c t + \frac{mA_0}{2}\cos(\omega_c + \Omega)t + \frac{mA_0}{2}\cos(\omega_c - \Omega)t \tag{4}$$

Assume that, as far as the system in question is concerned, when A(ω)=1, φ(ω) is any curve graph (see Fig.3).



$$\tau_c = \frac{\varphi(\omega_c + \Omega) - \varphi(\omega_c - \Omega)}{2\Omega} = \mathrm{tg}\theta$$

Fig.3 Envelope Time Delay

Phase shifts produced by the three system components on signals are, respectively, φ(ωc−Ω), φ(ω), and φ(ωc+Ω). Assuming that the amplitude modulation signal associated with the output of the system in question is ao(t), then

$$\begin{aligned} a_0(t) &= A_0\cos[\omega_c t - \varphi(\omega_c)] + \frac{mA_0}{2}\cos[(\omega_c + \Omega)t - \varphi(\omega_c + \Omega)] \\ &+ \frac{mA_0}{2}\cos[(\omega_c - \Omega)t - \varphi(\omega_c - \Omega)] \\ &= A_0[1 + m\cos\{\Omega t - [\varphi(\omega_c + \Omega) - \varphi(\omega_c - \Omega)]/2\}]\cos[\omega_c t - \varphi(\omega_c)] \end{aligned} \tag{5}$$

Comparing equation (3) and equation (5), the envelope phase shift between output signals and input signals φ_e is:

$$\varphi_e = [\varphi(\omega_c + \Omega) - \varphi(\omega_c - \Omega)]/2 \tag{6}$$

From equation (6), it is possible to see that envelope phase shifts produced by systems are identical to half the difference of phase shifts associated with upper boundary frequencies and phase shifts associated with lower boundary frequencies. There is no relationship between phase characteristics and whether or not φ(ω) is a straight line or a curve. Rewriting equation (5), one obtains:

$$a_0(t) = A_0[1 + m\cos\Omega(t - \frac{\varphi(\omega_c+\Omega) - \varphi(\omega_c-\Omega)}{2\Omega})]\cos[t - \varphi(\omega_c)/\omega_c]\omega_c \tag{7}$$

Comparing equation (3) and equation (7), it is possible to clearly see differences between system output signals and system input signals. It is also possible to see that the output signal envelopes are delayed a time τe:

$$\tau_e = [\varphi(\omega_c + \Omega) - \varphi(\omega_c - \Omega)]/2\Omega = \varphi_e/\Omega = \mathrm{tg}\theta \tag{8}$$

τe is defined as system envelope time delay at location ω_c. In equation (8), assuming $\varphi(\omega_c + \Omega) - \varphi(\omega_c - \Omega) = \triangle\varphi, 2\Omega = \triangle\omega$, $\tau_e = \triangle\varphi/\triangle\omega$;

When Ω->0, that is, envelope frequency is minimal relative to carrier wave frequencies, then:

$$\tau_e = \lim \triangle\varphi/\triangle\Omega = \mathrm{d}\varphi/\mathrm{d}\omega|_{\omega_c} \tag{9}$$

As far as derivations relating to envelope time delays in the article above are concerned--although wave amplitude modulation is used--with regard to frequency modulated and phase modulated signals, however, use is appropriate in the same way. Therefore, going through discussions, it is possible to arrive at that fact that--under certain conditions--signal envelope time delays are equal to group time delays. /64

2.3 Basic Principles Associated with Group Time Delays

On the basis of different test measurement principles, there are two types of measurement technologies associated with delay time periods. One is phase shift characteristic curve slope measurment techniques--also called static measurement methods. The second is modulation demodulation techniques. Of course, which ever type of measurement technologies they are, it is assumed in all cases that they are carried out under conditions where system amplitude and frequency characteristics are constants, that is, influences of amplitude changes on phase are not considered.

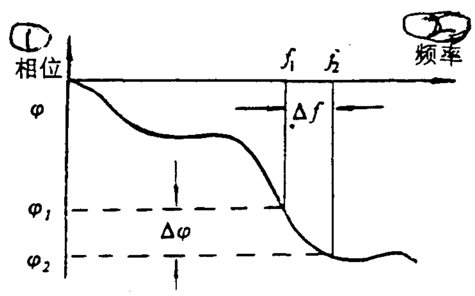


Fig.4 Phase Characteristic Slope Curve (1) Phase (2) Frequency

Group time delays associated with the first type of situation are obtained through calculations. These calculations are capable of being completed by static measurements associated with phase characteristics. Group time delay measurement instruments which have already been turned into commercial products--for example, vector network analyzers, resistance analysis instruments, and so on--are based, in all cases, on this type of method. Measurement systems which are composed of vector voltage meters or other high accuracy phase meters for which option is made also make use of this type of principle. Moreover, all derive group time delays through ω location phase characteristic slopes. The test measurement line and block diagrams are as shown in Fig.4 and Fig.5. System absolute time delays can be approximately expressed as:

$$\tau = -\triangle\varphi(\omega) / \triangle\omega \qquad (10)$$

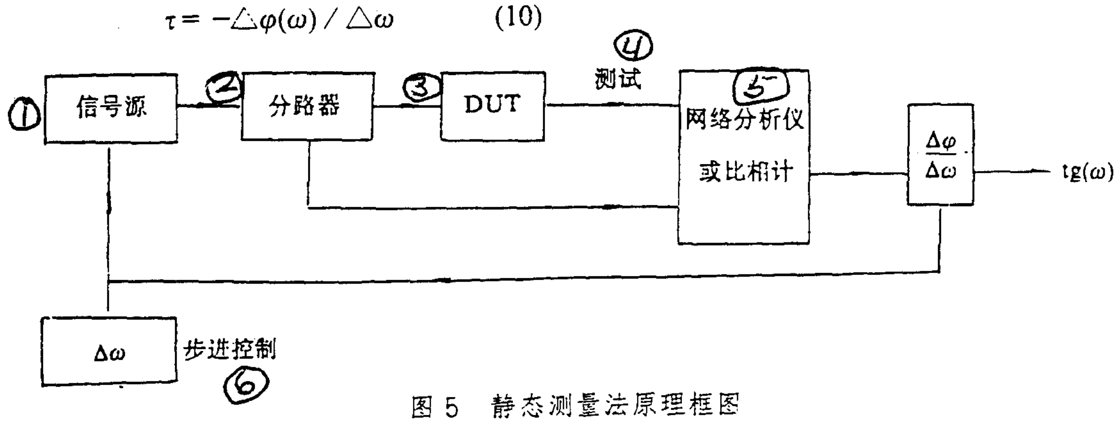


图 5 静态测量法原理框图

7 注: 图中 DUT 为被测器件

Fig.5 Line and Block Diagram of the Principles of Static Measurement Methods

Key: (1) Signal Source (2) Shunt (3) DUT (4) Test Measurement (5) Network Analyzer Instrument or Phase Comparator (6) Step Control (7) Note: In the Fig., DUT Is Measured Components.

From equation (10) and Fig.4, it is possible to know that the measurement technology in question requires the measurement of corresponding phase shifts at two different values ω_1 and ω_2 associated with high frequency signals. After that, group time delays are calculated in accordance with equation (10). Through altering the frequencies of high frequency signals, it is possible to measure system or network group time delay charcteristics. The second type of measurement technology is opting for the use of test measurements made of signals which are already modulated. After going through measured networks, demodulated and modulated signals are compared, obtaining values for group time delays. The principles are as shown in Fig.3 and equation (9). The test

measurement schematic is as shown in Fig.6. In the Fig., reference channels connect to demodulation devices. The purpose is to eliminate the influence of modulation devices on network time delays.

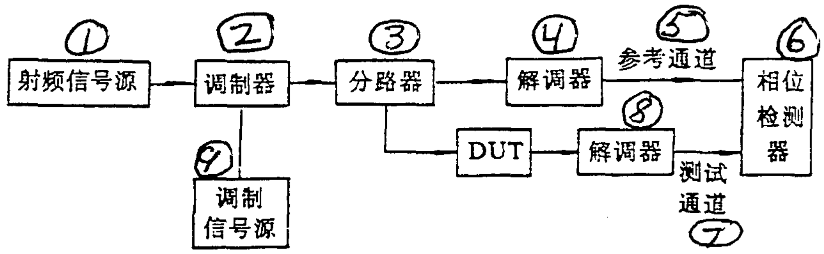


Fig.6 Line and Block Diagram of the Principles of Dynamic Measurement Methods

Key: (1) Radio Frequency Signal Source (2) Modulation Device (3) Shunt (4) Demodulation Device (5) Reference Channel (6) Phase Detector (7) Signal Source (8) Network Analyzer (9) Phase Comparator /65

3 ANALYSIS AND ACTUAL TEST MEASUREMENTS

3.1 Methods Associated with Phase Comparisions and Phase Measurements

At the present time, in China, a good number of test measurement systems built from unit vector network analyzer devices (for example, HP8510C Wiltron 360B) or making use of high precision phase meters and vector voltage meters are all based on static measurement methods. This type of method is a test measurement technology which is earliest and most direct. Due to static methods opting for the use of approximation calculations, it, therefore, brings to measurement techniques a certain limited nature--for example, the selection of Δf or $\Delta\omega$ (called windows) directly influences measurement results. In accordance with the definition $\Delta\varphi/\Delta f$, the smaller Δf is, the better it should be. However, as far as Δf being too small is concerned, due to resolution powers associated with φ being limited, there is no way to obtain accurate phase values. Working in this way, although it is possible to increase frequency resolution, there is still no way, however, to eliminate phase errors. In respect to enlarging Δf, it is possible to make group time delay resolution improve in respect to given phase resolutions. However, test measurement precision goes down. There exist latent phenomena leading to the homogenization of measurement results. The influences of window selection on measurement results are seen in Fig.7. As far as signal to noise ratios being low is concerned, it will also influence φ resolutions. Low signal to noise ratios will introduce phase fuzziness, thereby leading to the introduction of phase measurement fuzziness. Table 1 explains the relationships between phase resolutions and group time delay resolutions in cases associated with given windows.

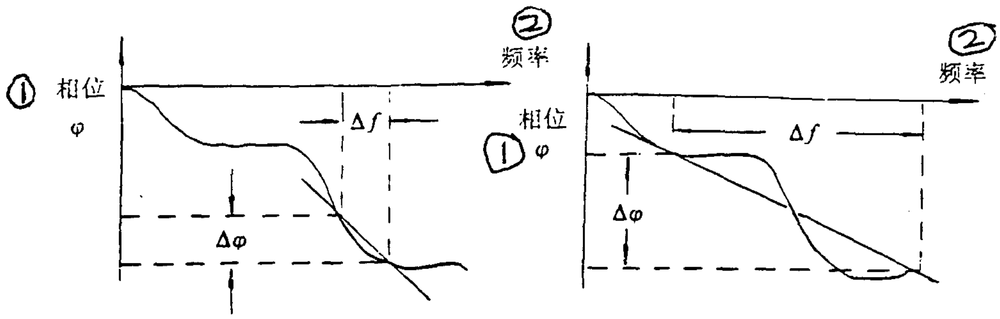


Fig.7 Influences of Windows on Precision
Key: (1) Phase (2) Frequency

Table 1 The Relationships Between Two Types of Resolutions for Given Window Conditions

(1) 信噪比(dB)	(2) φ 的分辨力(°)	(3) τ_g 的分辨力(ns)
80	+0.006	+0.06
60	+0.06	+0.6
40	+0.6	+6.0
20	+6.0	+60.00
$\tau_g = \triangle\varphi / 360 \cdot \triangle f$ $\triangle f = 278kHz$		

Key: (1) Signal to Noise Ratio (2) φResolution (°) (3) τg Resolution (ns)

Besides this--with regard to variable frequency system group time delay test measurements--static methods are then clearly powerless. The reason is that they go through frequency measurement phase comparators in order to calculate group time delays. However, phase comparisions are only possible at the same frequencies. When frequencies vary, there is no way to carry out comparisions. Thus, these is no way to obtain phase difference/66 values in order to calculate group time delays. In actual engineering, common use is made of frequency converters, signal repeaters, and so on. They belong to systems with different input and output frequencies. At the present time, with regard to group time delays associated with this type of system product, there is still a difficulty in world terms. During data searches, there are no reports in this area. There are only experts showing an interest in it. At the present time, there are people putting forward an option for the use of specialized frequency mixers to add basic oscillations, making different frequency systems turn into systems with the same frequencies in order to do measurements.

360B vector network analyzer instruments produced by the Willtron Company as well as group time delay test measurement instruments produced by the Anli Company both opt for the use of this technology, realizing group time delay measurements associated with systems having different frequencies. However, this type of method still opts for the use of terminal phase comparisions. After that, group time delays are calculated. They are still subject to limitations associated with phase measurement errors. Precision is low.

Opting for the use of modulation and demodulation technologies, it is also possible to carry out group time delay measurements associated with variable frequency systems.

Generally, when option is made for the use of sine wave modulation, group time delay resolutions are subject to very great limitations--for example, opting for the use of 20kHz to act as modulation signal, phase meter resolution is 0.01°. By contrast, group time delay minimum resolution is 1.5ns. From the analysis above, it is possible to know that the precision of test measurement systems which opt for the use of phase measurements are calculated from the formula below:

$$\triangle\tau = \triangle\varphi / 360 \cdot \triangle f$$

In this, $\Delta\varphi$ is phase measurement precision. It is subject to large influences from amplitudes. The smaller amplitudes are, the lower phase measurement precisions are. If phase measurement precision is 1°, when Δf is 1MHz, group time delay precision is 1ns. When Δf is reduced to be 100kHz, phase measurement precision is 10ns. From this, it can be known that resolutions as well as precisions associated with phase measurement methods are not high.

3.2 Time Interval Test Measurement Methods

Due to the fact that it is very difficult for test measurement precisions associated with phase measurement and phase comparison methods to reach the ns level, but, measurements of time intervals are still capable of reaching very high precisions, as a result, derivations associated with the preceeding demonstrate that--under certain conditions--network time delays are equal to group time delays. Based on this presupposition, we constructed a test measurement system. The line and block diagram is seen in Fig.8.

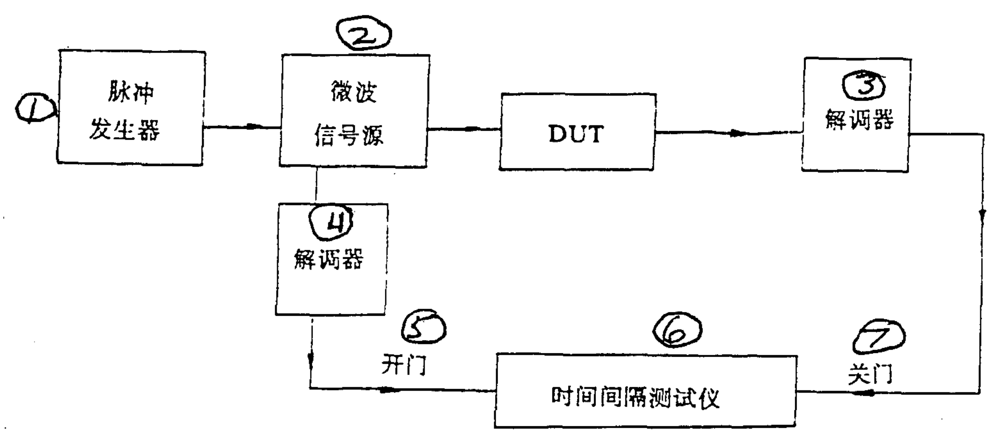


Fig.8 Time Interval Test Measurement System Line and Block Chart

Key: (1) Pulse Generator (2) Microwave Signal Source (3) Demodulator (4) Demodulator (5) Open Gate (6) Time Interval Test Measurement Instrument (7) Closed Gate

After pulse signals produced by pulse generators modulate microwave signal sources, they divide into two paths. One path is to act as open gate signals sent to time interval test measurement instruments after demodulation. The other path is microwave signals that have already been modulated being sent out to measured equipment. With regard to waves which have already been modulated and are associated with carrier wave frequencies sent out by measured equipment generating variations--through modulation--pulse signals are obtained to act as open gate signals sent to time interval measurement devices. Time interval measurement devices measure the time intervals between open gate signals and closed gate signals, thereby measuring group time delay.

Option is made for the use of τg results obtained by measuring time intervals to be time difference values. As a result, the precision of systems as a whole depends on the precision of final counting registers. In order to improve resolving powers and precisions within counting registers measuring time intervals, it is necessary to opt for the use of specialized test measurement technologies. As far as traditional counting register measurements of time intervals are concerned, if there is a need to reach ns levels of precision, there are problems. Even though it is possible to do, the costs are also extremely expensive. /67 However, if option is made for the use of analog internal difference methods to eliminate errors of ±1, counting registers are generally capable of reaching ns levels of precision. The test measurement principles are as follows.

The time interval associated with measured signals is Tx. From Fig.9, it can be known that Tx=Tn+T1-T2. Tn is the time interval between the first time base pulse after initiation of pulses and the first time base pulse after termination of pulses. T1 is the time interval between the start pulse and the first one after it. T2 is the time interval between the stop pulse and the first one after it. The measurement Tn is the cumulative total of the No individual counted pulses (time base signals) which appear within the time period in question. With regard to measurements of T1 and T2, use is first made, by contrast, of interpolation devices to produce amplifications of 1000 fold. In conjunction with that, T1' = 1000T1. T2'= 1000T2. Cumulative totals are made of the standard counted pulse numbers within this time period--N1 and N2--

in order to measure T1'and T2'. In this way, counting registers respectively count No, N1, N2 numbers of individual pulses. To is the standard pulse counting period. Then,

$$Tn = NoTo,\ T1' = N1To,\ T2' = N2To$$

Measured time period intervals are Tx=[No+(N1-N2)/1000]To

Although errors of ±1 still exist in T1 and T2, their size, however, is already reduced to one one thousandth. As a result, counting register resolution powers are improved three orders of

magnitude. For example, as far as To = 100ns(fo = 10MHz) is concerned--after opting for the use of interpolation techniques--it is possible to improve to 0.1ns--equivalent to opting for the use of 10GHz standard counting frequency signals.

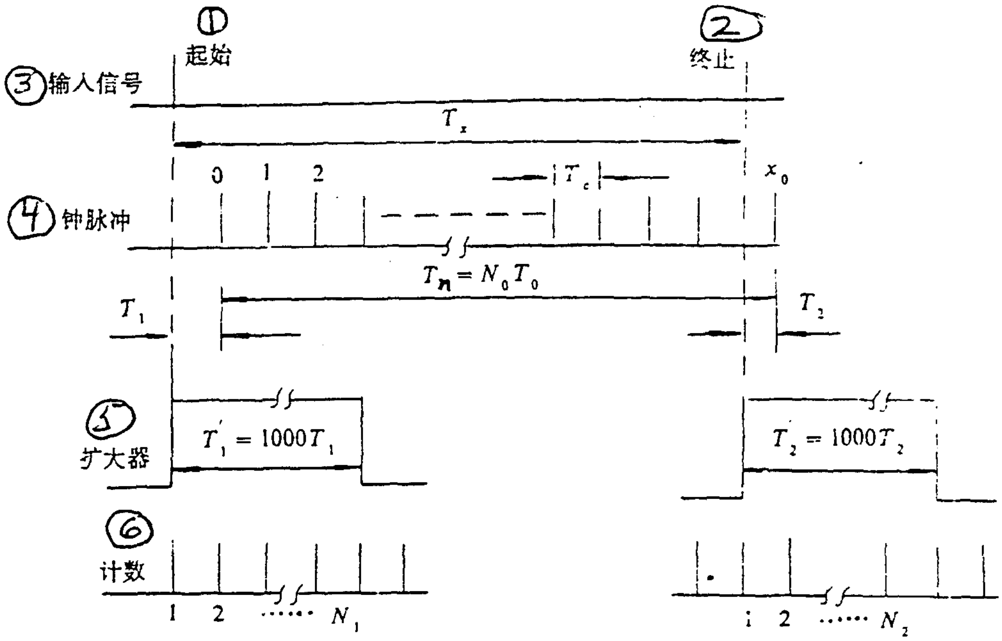


Fig.9 Diagram of Interpolation Method Principles

Key: (1) Start (2) Stop (3) Input Signal (4) Clock Pulse (5) Amplifier (6) Count

4 EXPLANATIONS OF SEVERAL KEY PROBLEMS

4.1 Design of System Components

4.1.1 Modulation and Demodulation Systems

Speaking in theoretical terms, no matter which type of system one opts for the use of, they are all possible (AM, FM, and PM all belong to group signals). However, during actual test measurements, reliance is placed on hardware levels in order to select modulation systems. Because the various individual parts in test measurement systems all require ns level leading edge effects, the difficulties involved are quite great. Telemetry center laboratories only possess experimental conditions for amplitude modulation systems. Therefore, system designs opt for the use of amplitude modulation methods. Analysis demonstrates that the system shown in Fig.7 is suitable for use with respect to any type of modulation. /68

4.1.2 Signal Sources

High stability low phase noise frequency sources are an indispensable prerequisite condition during group time delay test measurements. Because input signals associated with GPS systems on board missiles are -130dBm--under this electrical level condition--test measurement systems must operate normally. There is a need to deploy corresponding modulators, demodulators, and amplifiers. Moreover, ns level requirements make hardware enter into microwave frequencies. Corresponding hardware index requirements are even more severe. If not, noise will give rise to unstable system operations, leading to there being no way to carry out time period measurements or the production of extremely large deviations.

4.2 Test Measurement Results

As far as opting for the use of test measurement systems composed of this type of equipment is concerned, systems are capable of reaching stability levels smaller than 0.5ns as shown in Fig.10.

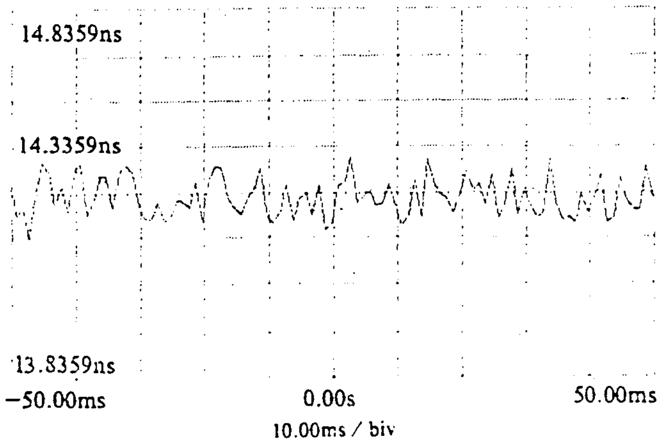


Fig. 10 Test Measurement Results

The hoizontal axis shown in the Fig. above stands for time periods used in test measurements. The vertical axis stands for measured time intervals. When the overall SPAN=1ns and resolution powers are 125ps for each grid, changes in test measurement results do not exceed four grids. That is nothing else than to say that the absolute time delay of the system is 14ns. Degree of stability is 0.25ns.

At the present time, the time interval measurement instrument which we make use of opts for the use of just this type of technology. The crystal oscillation is only 5MHz, but the resolution power still reaches 20ps. Precision is very high.

Fig.11 and 12 group time delay measurement systems constructed on the basis of the principles discussed above. Fig.11 is a system with the same frequency. Fig.12 is a system with different frequencies.

With regard to test measurements associated with systems having the same frequency, it is possible to reach very high precisions and resolution powers. Making use of the test measurement systems in question, comparative test measurements were carried out with regard to the Beijing radiometrology test measurement research institute standard delay lines in order to check on the reliability of test measurements by these systems. Test measurement results were as follows.

The time delay theoretical calculation associated with standard delay lines is 42.6ns. The measurement for the Beijing radiometrology test meaurement research institute is 42.8ns. The result we obtained was 42.6ns. The standard delay line frequency range is: 10MHz - 18GHz. Due to the fact that our test measurement system is subject to LNA influences, test measurements

were only carried out within the range of 2200-2300MHz. The resolutions and degrees of stability were both very high and /69 received serious attention together. (1) [(1) Note: Due to the fact that there are no delay standards associated with frequency variable systems, test measurement system precisions are only checked under conditions with the same frequency.]

4.3 Calibration Technology

Before introducing calibration technology, we will explain a concept--chromatic dispersion systems. Due to the fact that time delays are derivatives of phase characteristics, but phase characteristics are functions of frequency, absolutely linear systems do not exist. As a result, time delay characteristics are also nothing else than frequency functions. Due to the fact that phase characteristic linearity is not good and leads to time delays being functions of frequency, it is called chromatic dispersion. Any transmission system has chromatic dispersion. It is simply a matter of differences in the magnitude of chromatic dispersion, and that is all. Standard time delay line chromatic dispersions associated with Beijing radio metrological test measurement research center are very small. At 2200-2300MHz, the time delay variations are only 0.5ns. Moreover, considerations are not made of the influences of amplitude and frequency. Therefore, they are very close to systems without chromatic dispersion.

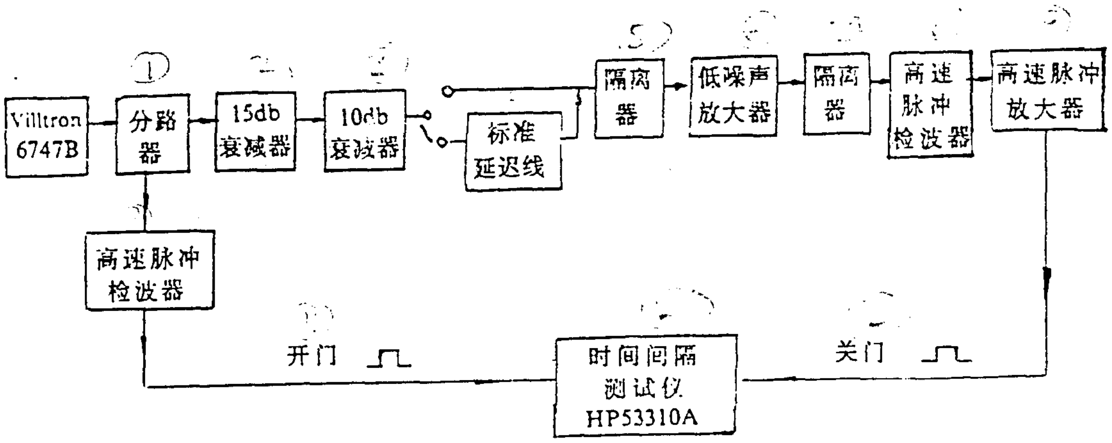


Fig.11 Test Measurement System with the Same Frequency

Key: (1) Shunt (2) Attenuation Device (3) Attenuation Device (4) Standard Delay Line (5) Disconnector (6) Low Noise Amplifier (7) Disconnector (8) High Speed Pulse Wave Detector (9) High Speed Pulse Amplifier (10) High Speed Pulse Wave Detector (11) Open Gate (12) Time Interval Test Measurement Instrument (13) Closed Gate

The key with regard to absolute group time delay measurements associated with systems having the same frequency lies in calibration. That is also nothing else but to say that--due to the existence of chromatic dispersion characteristics--which frequency point system time delay values take as standard.

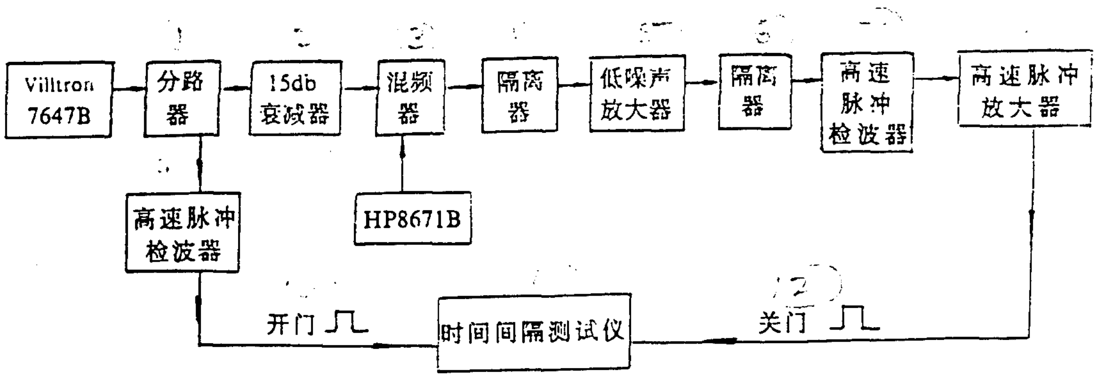


Fig.12 Frequency Variation Test Measurement System

Key: (1) Shunt (2) Attenuation Device (3) Frequency Mixer (4) Disconnector (5) Low Noise Amplifier (6) Disconnector (7) High Speed Pulse Wave Detector (8) High Speed Pulse Amplifier (9) High Speed Pulse Wave Detector (10) Open Gate (11) Time Interval Test Measurement Instrument (12) Closed Gate

In measurement reception systems associated with making use of GPS satellite signals to carry out positioning with regard to flying targets, GPS repeaters on board missiles belong to frequency variation systems. Generally, system time delay variations associated with GPS test measurement receivers directly receiving GPS signals are capable of reaching approximately 200ns. GPS repeaters include two parts--receiving and transmiting. Moreover, they also connect into the whole test measurement system. Speaking in terms of GPS positioning systems, this is a system quantity /70

which must be calibrated.

At the present time, there are three types of zero correction designs associated with GPS repeaters. Among these, errors associated with using group time delay methods are smallest. However, a good number of problems and difficulties still exist in association with engineering units inside China using this type of method in zero corrections. Test measurement systems studied by our telemetry center laboratory are as shown in Fig.11 and Fig.12. As far as opting for the use of pulse modulation methods to measure time intervals is concerned, it resolved difficulties associated with group time delay measurements of frequency variable systems.

5 TENTATIVE IDEAS AND CONCLUSIONS

Following along with ceaseless applications of GPS and constant rises in range finding precision requirements, the need for high precision group time delay measurements--in particular, group time delay measurements associated with systems having different frequencies--becomes more pressing by the day. This set of group time delay measurement systems set up by the Beijing telemetry technology research institute is capable of reaching very high precisions. In particular, with regard to frequency variation systems, it is possible to give group time delay measurement values associated with 1ns instabilities. This has still not been seen inside or outside China.

At the present time--on the currently existing foundation--our telemetry center laboratory has carried out certain probes with regard to group time delay measurements in signal transmission systems associated with frequency expansion systems. Due to group time delay distortion leading to correlation distortion in related receivers, enlargements of erroneous code rates are thereby given rise to. GPS satellite signals are also psuedo random code modulated. It is possible to receive signals which are submerged in noise. This is something traditional modulation systems cannot do. Therefore, making use of pseudo random code modulated signals to act as test meausurement signals to carry out component or system group time delay measurements is very important.

6 CONCLUDING REMARKS

With requirements for and the promotion of scientific research tasks, we developed the study of group time delay measurement methods, achieving a certain progress. Following along with unceasing increases in exterior measurement precision requirements, high precision frequency variation system group time delay test measurements are more and more important. Related theory and practical measurements with respect to group time delay test measurements will also obtain further improvement and strengthening.

The above are only a few of our attempts in the area of frequency variation system group time delay measurements. We respectfully invite various distinguished experts to point out what is not proper.

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